PAPER II PART A - STRUCTURED ESSAY

1. In an experiment to find the density of glass, using the principle of moments, you are provided with only the following.
   - (1) a piece of glass of irregular shape (mass $M \sim 50$ g)
   - (2) four weights of masses (m) 0.4g, 4.0 g, 40.0 g and 400.0g
   - (3) a meter ruler.
   - (4) a knife edge fixed to a support.
   - (5) a beaker of water.
   - (6) a piece of thread.

   (a) Draw an experimental setup that you would use to find the mass M by balancing the ruler at its centre of gravity. Label the masses and their corresponding distances l_1 and l_2 from the knife edge. (6cm availabel)

   (b) What is the advantage of balancing the meter ruler at its centre of gravity? *(2 lines)*

   (c) (i) Of the weights given in (2) above, which one is the most suitable for this experiment? Give the reason for your choice. *(2 lines)*

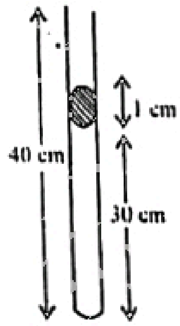
   (ii) write down an expression for M in terms of m, l_1 and l_2. *(one line)*

   (d) (i) What are the next experimental steps that you would perform in order to determine the density of glass without changing the position of the glass piece.? *(3 lines)*

   (ii) What is the measurement that you would take ? (say l_3) *(one line)*

   (e) Obtain an expression for the density of glass ρ in terms of density of water ρ_w . l_3 and l_1(or l_2) *(5 lines)*

   (f) Mass of another irregular piece of glass made of the same material but with an air cavity inside is 100 g. The dinsity obtained using the above procedure, was found to be 2.0×10^3 kgm^{-3}. If the density of glass is 2.5×10^3 kg m^{-3}, find the volume of the air cavity. *(5 lines)*



2. A student is given a narrow galss tube closed at one end having an air column trapped by a small mercury thread, as shown in the figure, The lengths of the air column and mercury thread at room temperatrre are shown in figure . Student is asked to measure the variation of the length of the air column (l) with the temperature (θ) when the tube is held vertically.

   (a) Suppose three separate water baths of heights 10 cm, 30 cm and 50cm are available in the laboratory, which bath is most suitable for this experiment ? *(one line)*

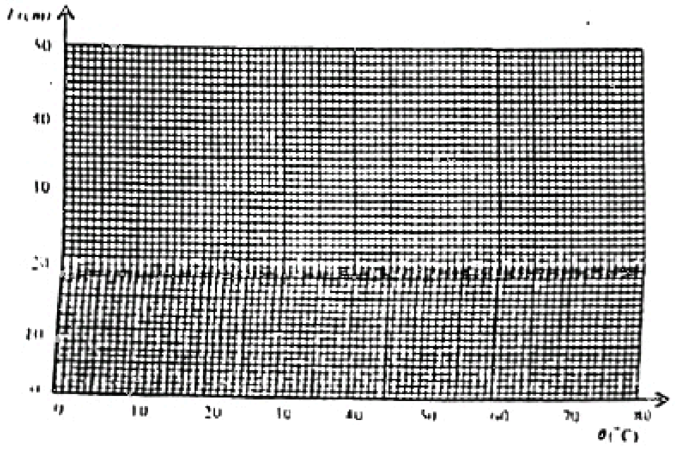
   (b) In order to ensure that the measured temperature of the water is the temperature of the air column, what experimental procedure should he follow ? *(3 lines)*

   (c) As the temperature is increased mercury thread will also expand. Can the student assume that the pressure of the air column remains constant ? Explain your answer. *(4 lines)*

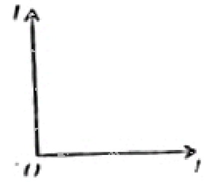
   (d) The following data were obtained by the student for θ and l.

θ(^{0}C)	30	40	50	60	70	80
l(cm)	30	31	32	33	34	35

   (i) Plot the graph l vs θ selecting ^{0}C and 0 cm as the origin. (9cm availabe!)



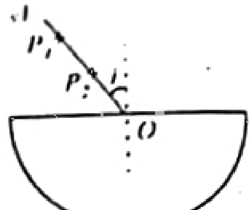
(ii) Determine the intercept of the graph on the I axis. *(one line)*
(iii) Calculate the gradient of the graph. *(2 lines)*
(iv) Use the above results to calculate the absolute zero temperature in Celsius *(3 lines)*



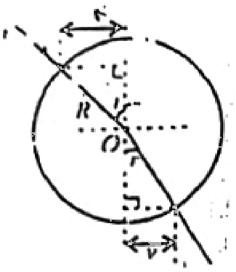
(e) Draw a rough sketch to show the variation of I with the absolute temperature T

(f) State the gas law which is verified by the graph in (e) *(3 lines)*

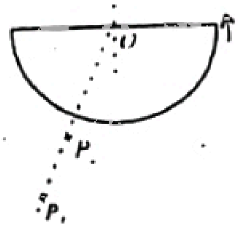
(3) You are to trace the passage of a light ray through a semicircular glass block and find a value for the refractive index. (n_g) of the glass. The block is kept on a sheet of white paper and two pins p_1 and p_2 are placed vertically along the line OA as shown in the figure. Here O is the centre of the straight edge of the block.



(a) Give the experimental steps needed to trace the passage of the light ray AO through the block using two other pins. *(3 lines)*

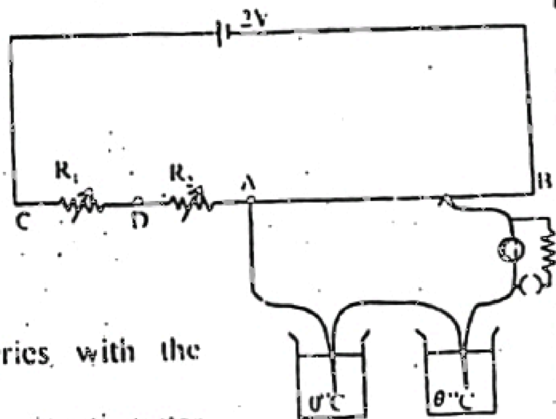


(b) Once the refracted ray is traced-out, a circle of radius R is drawn as shown in the diagram with O as the centre, and the distances x and y are measured.
(i) Write down sin i in terms of x and R. *(one line)*.
(ii) Hence find an expression for n_g in terms of x and y. *(2 lines)*
(c) What is the advantage of selecting R to be as large as possible? *(one line)*
(d) If you are asked to determine n_g by plotting a suitable graph, give the essential steps that you would follow. *(4 lines)*

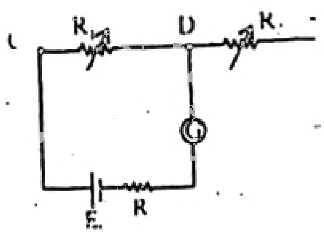


(e) A student suggests another method of determining n_g by measuring the critical angle (C) for the glass-air interface. In this method, the two pins are placed in front of the curved surface of the block as shown, and the images formed due to refraction from the glass-air interface are viewed, while rotating the block slowly about O in the anti-clockwise direction.
(i) Give the experimental steps that you would follow in order to determine C. *(4 lines)*
(ii) Write down an expression for n_g in terms of C. *(one line)*
(f) The first method mentioned may give a more accurate value for n_g than the second. What is the reason for this? *(2 lines)*

4 It is required to calibrate a potentiometer to study the variation of the e.m.f (E) of a thermocouple with temperature (θ)
The diagram show the basic circuit of such an arrangement. The internal resistance of the 2V cell in the circuit is negligible.



(a) What is the purpose of having resistors connected in series with the potentiometer wire AB? *(2 lines)*
(b) It is desired to have a potential drop of 4 m V across the potentiometer wire AB. If the potentiometer wire has a resistance of 10 Ω what should be the total value of the resistance R_1 and R_2? *(3 lines)*
(c) To find the current I in the potentiometer circuit experimentally, a standard cell of e.m.f E_0, a high resistance R and a galvanometer are connected across R_1 as shown in the figure.



(i) What is the purpose of having R other than protecting the galvanometer? *(one line)*
(ii) What should be the value of R when the appropriate measurement is taken? *(one line)*
(iii) What procedure should be adopted to obtain I ensuring that the potential drop across AB is maintained at 4 mV ? *(2 lines)*
(iv) Write down an expression for the current I in terms of R_1 and E_0 *(one line)*
(d) If the total length of the potentiometer wire is 600 cm, write down and expression for the potential drop per unit length k in terms of L *(2 lines)*
(e) How would you determine the e.m.f. of the thermocouple at a given temperature ? *(3 lines)*
(f) Give a specific advantage of using a thermocouple for measuring temperatures *(2 lines)*

PAPER II PART B - ESSAY

1. Read the following passage carefully, and answer the questions given below:

Divers, acrobats, and ballet dancers perform many graceful rotational movements. All these movements can be explained in terms of the physical concepts related to rotational motion.

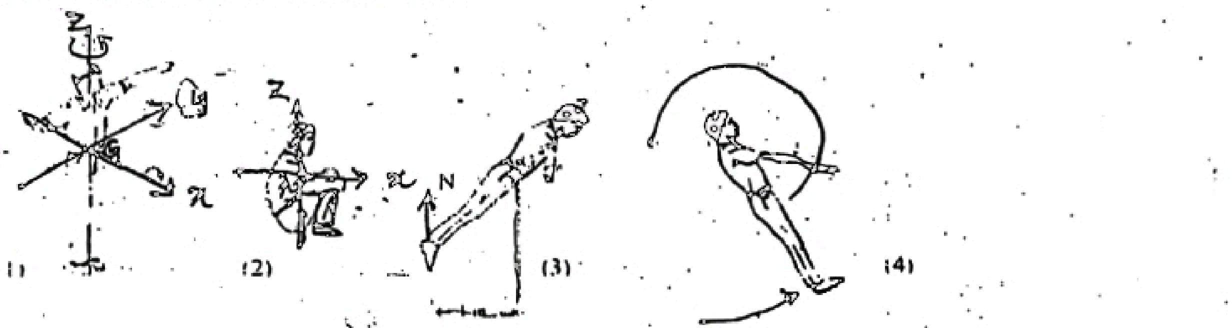
The rotation of a human body can be related to three mutually perpendicular axes which pass through the centre of gravity (G) as shown in Fig (1). Rotation about the y-axis is called a sumersault, about the z-axis it is a twist, and about the x-axis it is a pinwheel motion. While performing the twist the body rotates in the plane xy.

The moments of inertia (I) about these axes depend on the position of the arms and legs. In general I_z is small than I_x or I_y. For an average person standing as depicted in figure (1). the values are $I_z = 3.4$ kg m², $I_x = 19.2$ kg m², and $I_y = 16.0$ kg m². In the "tuck" position shown in Fig (2). the values are

$I_z = 2.0$ kg m² and $I_x = I_y = 4.0$ kg m².

The most obvious way a diver can acquire a somersault motion on take off is by using a diving board. Fig (3) shows how the person can acquire angular momentum about the axis y. He merely leans forward as he jumps. The normal reaction N due to the board produces a torque about his centre of gravity.

Now consider how a person acquires somersault motion while he is in free fall. The body is held rigid and the raised arms are brought rapidly forward in a "arm swing" motion as in Fig (4). As the arms are brought down, the body will rotate in the opposite sense. The axis of rotation is at the shoulders. The somersault will continue as long as the arms perform this "arm swing" motion. However, the rotation of the body is slow compared to the rotation of arms.



(1) (2) (3) (4)

(i) Name the plane of rotation of the person in fig (1) when he performs a sumersault.

(ii) Mass of an object measures the inertia for linear motion. What does the moment of inertia of an object about a given axis measure?

(iii) How can a person change his moment of inertia about a given axis on his own?

(iv) For the person shown in Fig (1) I_x is smaller than I_z or I_y. What is the reason for this?

(v) The person shown in Fig. (1), makes a somersault with angular velocity 2.0 rad s⁻¹. While in rotation he changes to the position shown in Fig (2).

(a) Calculate the new angular velocity of the person.

(b) Calculate the change in rotational kinetic energy of the person. How do you account for this change?

(vi) If the mass of the person is 60kg determine his initial angular acceleration about his centre of gravity when he takes off the board as in Fig (3)

(vii) when the arms are swinging rapidly as in Fig. (4), what is the reason for the slow rotation of the body?

(viii) Is the angular momentum of the person in Fig (4) conserved about and axis going through his shoulders? Give reason for your answer

(ix) We use this "arm swing" technique instinctively when we are about to slip on a wet floor. If our feet start to slip forward, a rapid arm swing motion apposite to that in Fig (4) is executed. Briefly explain the reason for this

2. A resonance tube of variable length closed at one end is made to resonate with a tuning fork frequency 512 Hz. It was observed that the shortest length of the tube at which resonance occurred was 16.6cm. As the length of the tube was increased, resonance occurred for the second time at 50.7 cm. The temperature in the laboratory was observed to be 27°C.

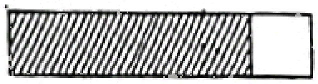
   (i) Draw the standing wave patterns in the resonance tube for the two situations above.

   (ii) Find the end correction of the tube and the velocity of sound under the experimental conditions.

   (iii) If the density of air at S.T.P. is 1.2 kg m^{-3}. Calculate a value for γ the ratio of principal specific heat capacities of air. Assume that the air behaves as and ideal gas (Standard atmospheric pressure = 1.0×10^5 N m^{-2})

   (iv) For a gas explain why the specific heat capacity at constant pressure (C_p) is greater than that at constant volume (C_v).

3. Write down an expression for the capacitance C of a parallel plate capacitor filled with a material of dielectric constant k. Identify the symbols used.



A dielectric slab of thickness 3 mm and of dielectric constant 4 is placed between the plates of a parallel plate capacitor. The plates of the capacitor are square in shape.

Each of area 0.2 x 0.2 m^2 and their separation is 3 mm. The slab covers ¾ of the plate area of the capacitor as shown in the figure. Find the capacitance of the system.

When a potential difference of 1 kV is established between the plates by connecting a battery across them, it was observed that the slab moved a distance of 1 mm during a short time interval.

   (i) What would be the increase in capacitance and increase in energy stored in the capacitor due to the movement of the slab ?

   (ii) By taking this increase in energy to be equal to the work done on the slab, calculate the force exerted on the slab. Assume that the force on the slab remains constant during the short time interval mentioned above.

   (iii) Find the energy supplied by the battery during the same time interval ($\epsilon_0 = 9 \times 10^{-12}$ Fm^{-1})

4. A soap film is formed on a wire frame. A loop made with and elastic string of unstretched length 10 cm is kept on the surface of the film and the film inside the loop is broken. The cross-sectional area of the string is 1.25×10^{-6} m^2 and the Young's modulus of the material of the string is 7.0×10^{4} N m^{-2}. Surface tension of the soap solution is 2.5×10^{-2} N m^{-1}.

   (i) Calculate the diameter of the loop.

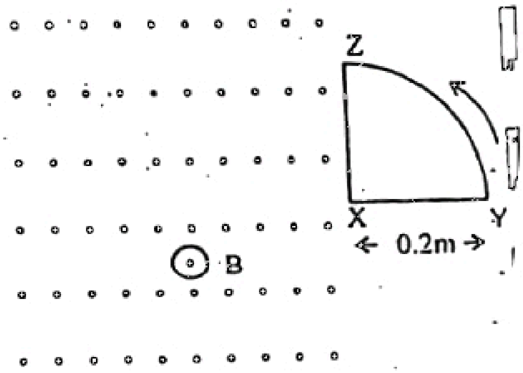
   (ii) What is the change in surface energy of the film ?

   (iii) Calculate the energy stored in the string.

   (iv) If one half of the length of the string was made with an inextensible string, draw the shape of the loop when the film inside is broken.

5. Answer either part (a) or part (b).

(a) A flat loop of wire XYZ in the form of a quarter of a circle of radius 0.2 m rotates uniformly about the point X in the plane of the paper. The sense of rotation is given by the arrow. The loop passes in and out of a region of uniform magnetic field of flux density (B) 0.5 T as shown, making one complete revolution in 0.8 seconds.



   (i) What is the maximum magnetic flux through the loop during its rotation ?

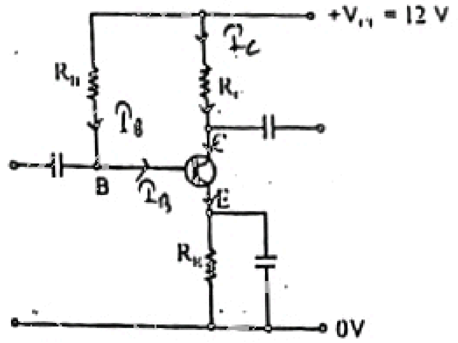
   (ii) Plot with relevant values the variation of magnetic flux through the loop with time t during one complete revolution assuming that the loop is at the position indicated in the diagram at t=0.

   (iii) What is the maximum magnitude of the induced e.m.f. generated in the loop ?

   (iv) Draw the induced e.m.f. in the loop, with relevant values, as a function of time on a time scale of 0 - 0.8 s with the same assumption for t = 0 as in (ii)

   (v) Instead of a closed loop, if only the two conducting wires XY and XZ are present, what will the maximum and minimum values of the induced e.m.f. across the ends X and Y or, X and Z of each wire ?

(vi) Plot the variation of induced e.m.f. across one wire as a function of time for one complete revolution.

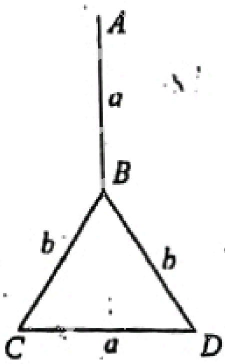


(b) With the aid of a clear labelled diagram show the structure of a junction transistor.
What are the configurations in which a transistor can be used in electronic circuits ? Illustrate these configurations with simple circuits. Which of these is commonly used in amplifier circuits ? Give the reasons for this

In the amplifier circuit shown, it is desired to have I_C = 2mA, V_{CE} = 6 V and V_E = 1.2 V. If β = 100 and V_{BE} = 0.6 V. find suitable values for R_B, R_C and R_E . What are the values of V_B and V_C ?
If a small sinusoidal voltage is connected to the input of the amplifier, sketch the input and output voltage on the same time scale,
V_{CE} is usually chosen to be around $\frac{V_{CC}}{2}$. Explain why

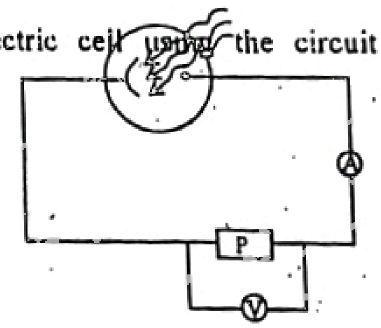
Answer either part (a) or part (b).

(a) The metal frame shown in the figure is made with uniform rods of two different materials a and b. All the rods are of identical length and cross sectional area. The thermal conductivity of the material a is twice that of the material b. All the rods are well lagged so that no heat it lost to the surrounding. If the end A is maintained at 50°C and the junction C is maintained at 10°C, find the temperatures of the junctions B and D in the steady state.

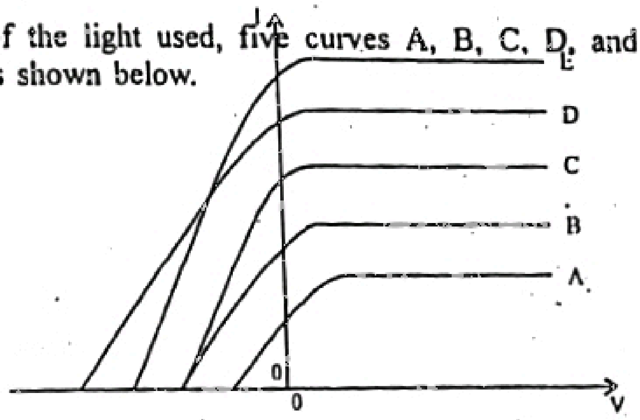


If the frame is made of the same material and end A and junction C are maintained at 50°C and 10°C respectively as before, what would be the temperatures of the junctions B and D in the steady state ?

(b) An experiment is carried out with a photoelectric cell using the circuit shown below. Here P represents a d.c. voltage supply.



By varying the intensity and frequency of the light used, five curves A, B, C, D, and E of photo current (I) vs voltage (V) were obtained as shown below.



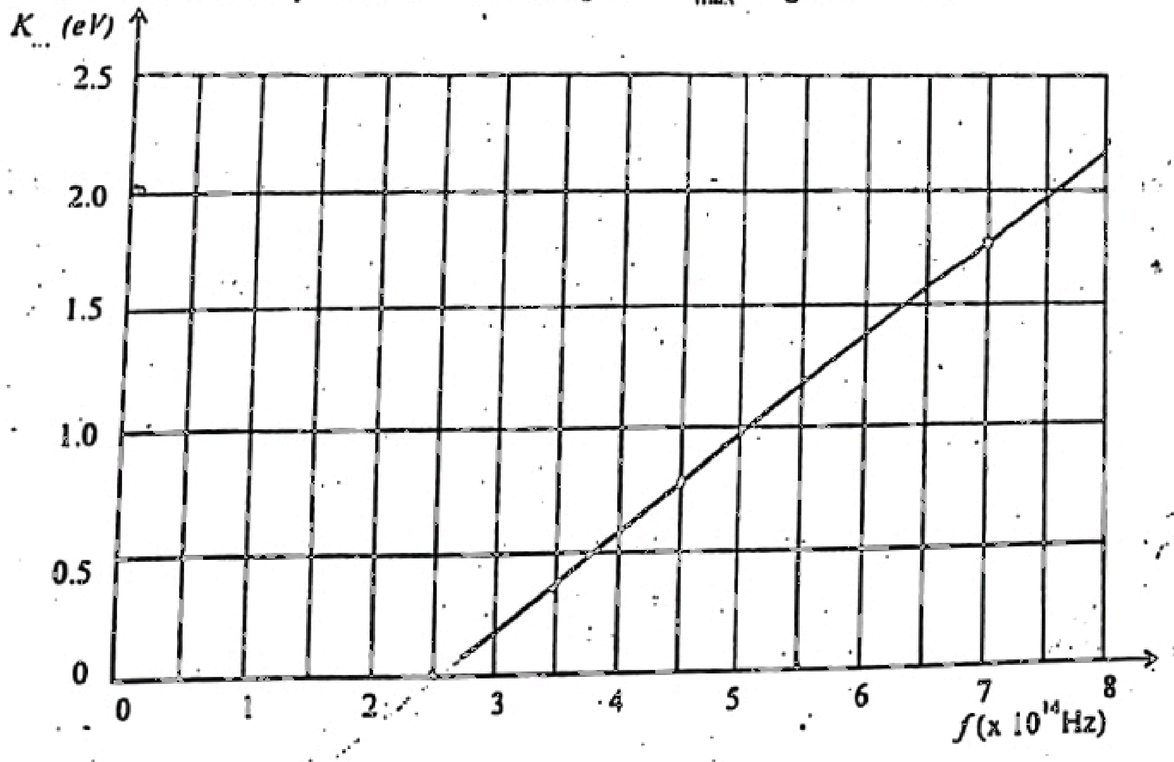
(i) Which two of the curves correspond to incident light of the same frequency but of different intensities ?
Give the reason for your selection.

(ii) Which of the curves corresponds to the highest frequency of the light used ? Give the reason for

(iii) Which of the curves corresponds to the highest intensity of the light used ?

(iv) Which of the curves corresponds to the situation where the highest kinetic energy electrons ar ejected from the photoelectric surface ?

(v) In such an experiment the maximum kinetic energy (K_{max}) of ejected electrons b monochromatic light of frequency (f) is measured for several different values of f. The lir best fit to the experimental values of f and K_{max} is given below.



Write down an expression which relates K_{max} to f in terms of Planck constant (h) and th photo-electric work function (ϕ) of the photosensitive material.
Use the above graph to find the following.

(1) A value for the Planck constant (in Js).
(2) Threshold frequency of the photo-electric material.
(3) Work function of the photo-electric material (in eV)
(4) The stopping potential for $f = 7.5 \times 10^{14}$ Hz.
(electronic charge = 1.6×10^{-19} C; 1 eV = 1.6×10^{-19} J)

If the experiment was repeated with the intensity of the light source being doubled, would yo expect a different straight line to that of the above ? Explain your answer